CLARKE®

Date: October 10, 2018

Instructions for Installing Ni-Cad Batteries

Warning: Ni-Cad individual cells may have been shipped "dry"! Please verify cells are filled with the proper electrolyte (Potassium Hydroxide) before connecting the completed battery sets to the engine or to a battery charger or both. *Batteries will be destroyed if connected prior to filling.* Also, please contact Clarke for helping source the proper electrolyte for these Ni-Cad cells.

NOTE: For battery specifications refer to C135691

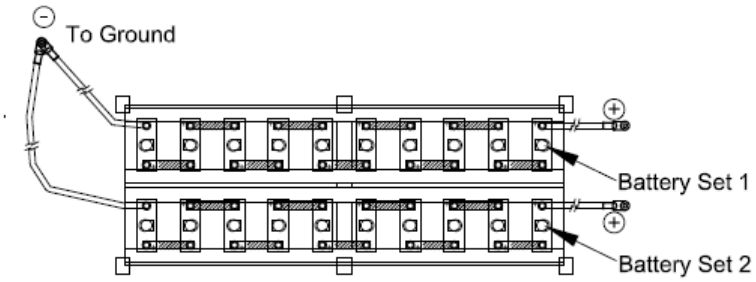
Tools Required:

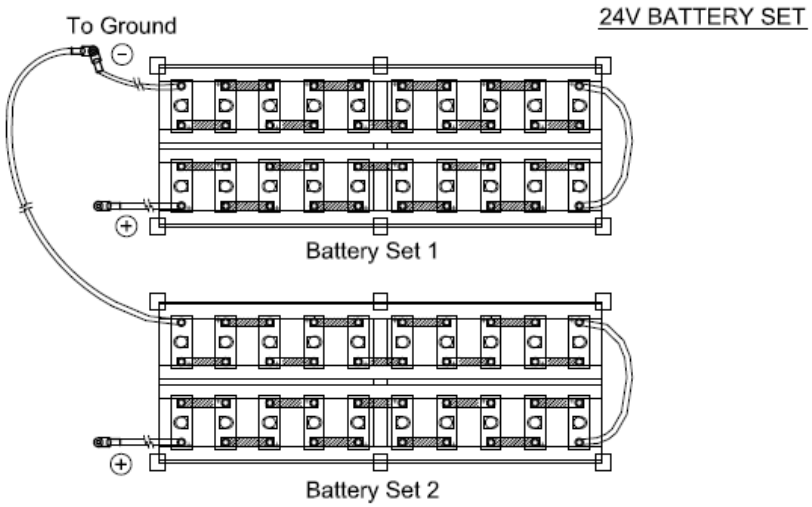
- M8 Socket
- Socket Wrench or Impact w/ Extension

Installation Instructions:

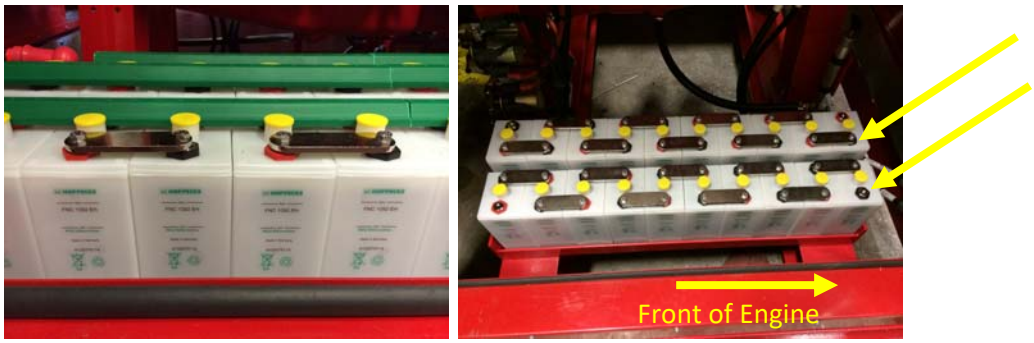
Clarify whether the system is 12V or 24V and use diagrams below for reference.

12V BATTERY SET



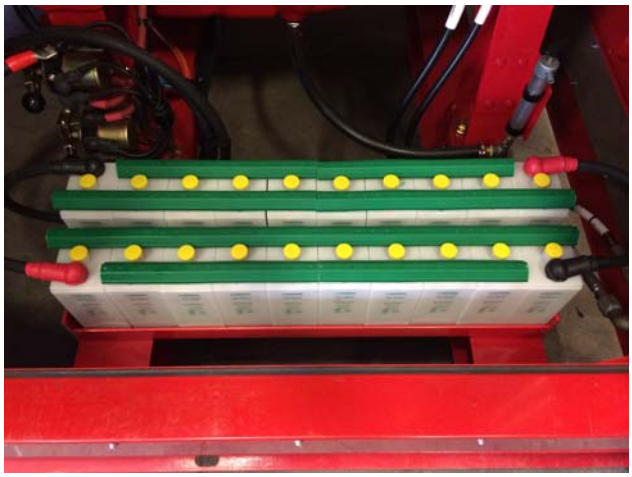


- Place Batteries in rack with alternating polarity, starting with negative to the outside of the engine on front most cell. Same orientation both rows of cells. (disregard plates on terminals).

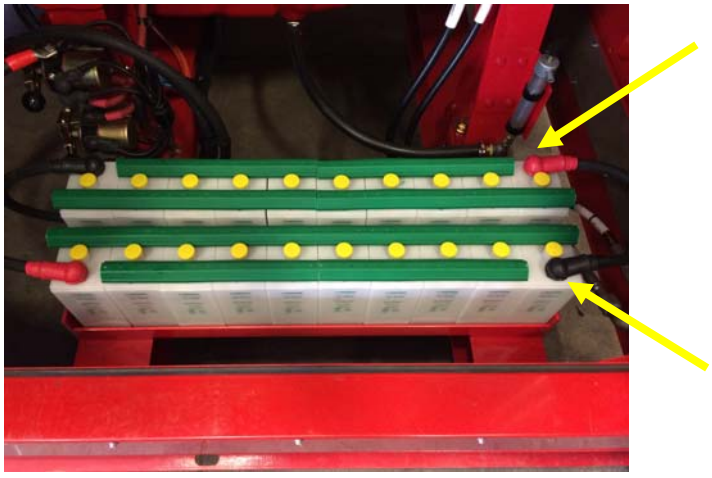


- Plates are installed with (2) Washers and (2) M8 Bolts, all provided. Plates are installed staggered as shown below. (Connector plates may vary due to battery size and height)

- Cut green plastic channel to length, covering all terminals except outer most corners terminals as shown. (disregard terminal cables)



- Attach jumper cable from negative to positive on front most terminals, for 24V system. For 12V system no jumper required, see initial diagram for reference.



- Remove all yellow caps and replace all with white hinged caps provided. (press down white caps until sealed)

- Refer to the commissioning document, C135675, for requirements when filling batteries with Electrolyte fluid.
- For any operation & maintenance issues see C135676.

Assembly and Installation Instructions

Stationary Nickel-Cadmium Batteries with FNC cells

(Batteries / Racks / Cabinet)

It is assumed that only qualified personnel are engaged in assembly and installation of the components provided. Qualified personnel are persons who, on the strength of their training, experience and instruction, together with their knowledge of the relevant standards, provisions, accident prevention regulations and operating conditions, have been authorised by those responsible for the safety of the components / installation, to carry out the relevant necessary work, with the ability to recognise and avoid possible hazards. Amongst other things, knowledge of First Aid and of local rescue equipment are also necessary.

Failure to observe the instructions on use, repair with non-original parts, unauthorised intervention, or use of additives to the electrolyte shall render the warranty void.

Safety instructions

The following safety measures relate to the handling of batteries and are to be observed in connection with all operating instructions contained in these instructions.

Observe assembly and installation instructions and display visibly at point of installation.
Work on batteries only after instruction by qualified staff. The operating instructions must always be accessible to personnel responsible for dealing with batteries.

Wear eye protection and protective clothing when working with batteries.
Observe accident prevention regulations.

No smoking. No open flame, embers or sparks in the vicinity of the battery, to avoid risk of explosion and fire.

Explosion and fire risk, avoid short-circuits.
Warning! Metal parts of the battery cells are always live. Never place objects or tools on the battery. Ensure adequate ventilation of the battery room, so that explosive gases produced during charging are drawn off (see DIN EN 50272-2).

Have eye rinsing bottle ready at hand. If electrolyte splashes into the eyes or onto the skin, rinse with plenty of clear water and seek immediate medical advice. Clothing contaminated with electrolyte is to be washed thoroughly.

Electrolyte is highly corrosive. In normal operation there is no possibility of contact with the electrolyte. Electrolyte is released only if the cell housing is destroyed.

Do not tilt the battery
Use only approved lifting and conveying equipment e.g. lifting gear. Lifting hooks must not cause damage to cells, connectors or connection cables.

Dangerous electrical voltage.
Use only suitable tools and measuring instruments.

First Aid measures

Electrolyte in contact with the eyes:

- Rinse immediately with plenty of water for at least 10 minutes.
- If available, rinse the eyes with boric acid solution.
- Immediately visit the eye clinic/eye casualty department.

Electrolyte in contact with the skin:

- Immediately remove clothing contaminated by electrolyte, and wash affected areas of skin with plenty of water. Visit doctor if any problems occur.
- Skin which has been in contact with electrolyte has a soapy consistency. Continue rinsing with water until normal skin condition has been restored.

If electrolyte is swallowed:

- Rinse out mouth immediately with plenty of water, and repeatedly drink large amounts of water.
- Do not induce vomiting. Call emergency medical service immediately.

Protection against dangerous body contact currents

In stationary battery installations, measures must be taken to guard against direct and indirect contact. For battery installations this protection can take the form of obstacles or distance. Battery installations with a rated voltage of more than 120 V must be accommodated in enclosed, electrical operating areas. Doors of battery rooms and cubicles count as obstacles when they are identified by the following warning plates (fitted externally):

- Warning plate “Dangerous Voltage”, if the battery voltage exceeds 60 V (see ISO 3864)

- Prohibition sign: "No fire, naked flame or smoking"
- Warning plate "Battery Room" to indicate electrolyte, explosive gases, dangerous voltages and currents.

Protection against direct contact may be provided through the insulation of live parts, by covering or enclosure, or by obstacles or distance. Batteries with a rated voltage of less than 60 V require no protection against direct contact. If covering or enclosure is chosen for protection against direct contact for a battery with a rated voltage in excess of 60 V, then at least protection type IP2X or IPXXB must be used.
Protection against indirect contact may be provided by means of automatic disconnection, by the use of equipment of protection class II or by isolation. In particular applications this protection may also be provided by the use of non-conductive areas or by earth-free, localised potential equalisation.
Certain protective measures require a protective conductor. These protective conductors may contain no switches or overcurrent devices. Battery racks or battery cubicles made of metal must be either connected to the protective conductor or else isolated from the battery and the point of installation. If overcurrent devices are used, then disconnection of the connected equipment must take place within five seconds.

Rack or cabinet assembly

Before commencing rack or cubicle assembly:

Before starting assembly it must be ensured that the battery room is clean and dry and has a door which can be closed. The battery room must, as described above in the section "Protection against dangerous body contact currents", be provided with warning signs conforming to DIN EN 50272-2.
Particular attention should also be paid to the following:

- Ensure correct floor loading and floor quality (access routes and battery room)
- Ensure that the mounting surface (floor of the battery room or electrolyte tray) is resistant to electrolyte
- Protection against sources of ignition (naked flame, glowing matter, electrical switches) in the vicinity of the cell opening, 500 mm "filament distance" as specified in DIN EN 50272-2
- Ensure adequate ventilation
- Agreement with other persons working in the same room (ensures trouble-free installation).

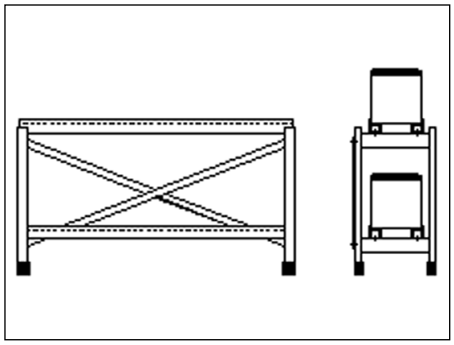
HOPPECKE will be pleased to help you in procuring suitable racking.

Scope of delivery of racks/ cabinets and documentation

The goods delivered should be checked for completeness and for any signs of damage. All oarts should be cleaned if necessary. The accompanying documentation should be noted and followed. This documentation should comprise an assembly drawing for the rack or cubicle, together with battery connection instructions. If the documents required for correct assembly of the rack are missing, they should be requested before starting assembly. Only undamaged cells may be used, since otherwise the whole battery may be adversely affected by escaping electrolyte.

Rack assembly

The rack is assembled in accordance with the instructions supplied (example below).



We recommend that the individual side elements are assembled first. The side elements are then erected and the diagonal connectors are bolted to the reverse. The horizontal support rails on which the cells will subsequently stand are then assembled and screwed into place. The spacing of the support rails should correspond to the cell dimensions. Finally check the stability of the rack, and that all screw and clip connections are secure.
The rack is then brought into its final position and aligned using a spirit level and the spacer material supplied (e.g. adjustable insulators).

Setting-up the rack

The rack is set up in accordance with the erection drawing supplied. The following minimum clearances are to be observed:

- Clearance between rack and wall: min. 50 mm
- Clearance between cell and wall: min. 100 mm
- Aisles between racks: min. 500 mm

If component voltages in excess of 120 V are reached or if the rated voltage of the battery is above this value, then a minimum distance of 1.5 m is to be maintained between non-insulated connections or connectors and earthed parts (e.g. water pipes, heating) and between the end terminals of the battery.

Setting-up the cabinets

Normally battery cubicles are supplied fully assembled. If however the cubicle is supplied in separate parts, then it should be assembled in accordance with the assembly drawing supplied, as for the racks. The following minimum clearances are to be observed:

- Clearance between cubicle and wall: min. 50 mm
- Aisles between cubicles: min. 500 mm

HOPPECKE FNC (fibre-structured) nickel-cadmium cells are designed for use solely in the upright position. These cells may never be installed in a lying position or tilted at an angle.

Ventilation requirements

It is essential to ensure that the battery room or cubicle has adequate ventilation. In subsequent operation, the ventilation of the battery room should keep the hydrogen concentration during battery charging below the threshold of 4% by volume, in accordance with DIN EN 50272-2.
The volume of air which must be changed hourly may be calculated by the following formula:
$Q = 0.05 * n * I$
Q = volume of air in m^3/h
n = number of individual cells in the battery
I = charging current in A

The battery room or battery cabinet may be ventilated by natural or forcedl means. If natural ventilation (airflow

0.1 m/s) is used, then the inlet and outlet vents should have a minimum cross-section, which is calculated as follows:
A = 28 * Q
A = cross-section of vent in cm^2
Q = volume of air in m3 / h

The inlet and outlet vents are to be provided at suitable locations to obtain the most advantageous conditions for exchange of air.

Installation of the battery

Use insulated tools and wear suitable clothing! Do not wear rings, watches or metal objects when working on the battery installation.

Equipping the rack or cabinets

FNC cells are basically supplied sealed by yellow transport plugs. These cells may be filled and charged (GUG) or unfilled and uncharged (UUU). The yellow transport plugs remain on the cells until completion of connection and installation of the battery (important to avoid atmospheric oxygen coming into contact with the electrodes!).

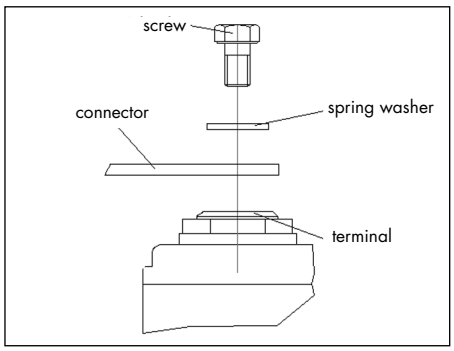
In general, when handling the cells during installation of the batteries, the yellow transport plugs should be used for sealing. Unfilled cells in particular should always be sealed with a yellow transport plug. After removal of the yellow transport plug, the cell should be filled with electrolyte immediately.

If the cells are unfilled (UUU), then they should be filled only after the battery has been installed and connected. Before the cells are placed on the rack or in the cubicle, they should be individually checked and cleaned. In particular the contact surfaces of the terminals and the connectors should be in a clean and perfect condition. The polarity of the cells should also be checked with a suitable voltmeter. Place the individual cells on the rack or in the cubicle one after the other, with correct polarity and as shown on the connection drawing, and at right-angles to the horizontal support rails. It is not necessary to maintain a distance between the individual cells.

Connection of the battery

After fitting in place, the individual cells are connected into groups. Connection may be made with both insulated and non-insulated connectors. Only original HOPPECKE accessories may be used for this inter-connection.

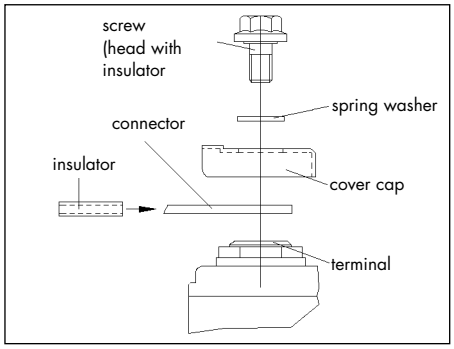
Non-insulated connectors



The contacts must be clean and free from any traces of corrosion. General, spring washers are used. These spring washers ensure, when the screws are tightened with the correct torque, a lasting and secure fit of the connectors on the terminal posts.

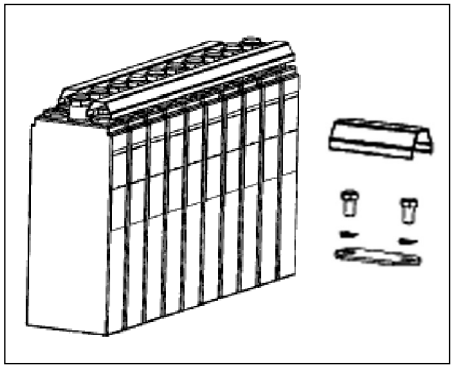
For tightening the terminal screws with the correct torque, only torque spanners with sockets may be used. Insulated terminal screws in particular may be damaged through the use of ring or jaw spanners.

Insulated connectors



When using insulated connectors, care has to be taken during assembly to avoid the clamping of plastic parts between conductive metal parts lying on top of one another. An appropriate check is to see that there is slight play between the plastic cover caps and the plastic insulation of the connectors when they are moved gently to and from in a horizontal direction. Only then can correct assembly be ensured. Without this play there could be clamped plastic parts which may melt or scorch when current flows. This can lead to reduced performance and increased risk of fire.

Non-insulated connectors with insulator cover:



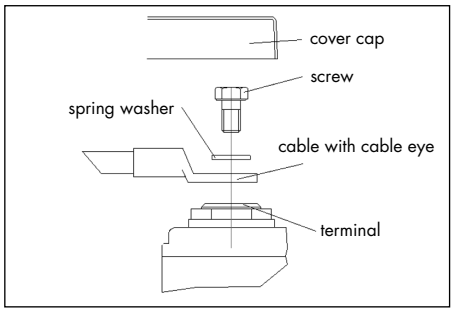
Like the non-insulated connectors, the contacts must be clean and free from any traces of corrosion. Principally, spring washers are used. These spring washers ensure, when the crews are tightened with the correct torque, a lasting and secure fit of the connectors on the terminal posts.

For tightening the terminal screws with the correct torque, only torque spanners with sockets may be used. Insulated terminal screws in particular may be damaged through the use of ring or jaw spanners.

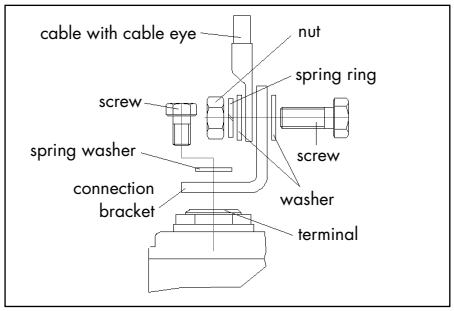
The isolation caps are available as a yard good, also in UL listed material. The isolation cover can be used both for 3 mm and for 6 mm of standard connectors. By using these insulator cover we are reduce both, the assembly and dismantling time, and the risk of faulty assembly.

After the individual cells have been interconnected by means of connectors, the individual rows, levels and tiers are connected. The individual cell groups are interconnected. Here, care should be taken with regard to the cross-section of the group connectors. Only approved cable types should be used.

Group or end connectors



Group or end connectors with connection bracket:



The wiring of the group and end connectors should be proof against short-circuits. This means that the wiring used should have a dielectric strength of at least 3 kV, or else an air gap of at least 10 mm should be maintained between the wiring and electrically conductive parts. Alternatively, additional insulation may be used. Any mechanical loading of the end terminals is to be avoided by the fixing of the group and end connectors.
The connectors ensure the optimal flow of current and therefore require perfect contacts. For this reason a torque spanner should be used for tightening. The starting torque of the screws depends on the thread size of the screws and the design of the terminal screw:

Thread size	Insulated terminal screw	Non-insulated terminal screw
M8	16 Nm ± 1 Nm	20 Nm ± 1 Nm
M10	20 Nm ± 1 Nm	25 Nm ± 1 Nm

Concluding work

After connection of the battery, the yellow transport plugs are removed from all cells. These transport plugs should be stored near the battery for possible reuse. If the cells concerned are unfilled (UUU) then they should be filled with electrolyte up to the level of the min. mark + 10 mm. During filling with electrolyte, slight heating may occur. Topping-up with electrolyte to the max. mark takes place after the battery has been brought into operation for the first time. The cells must be filled with electrolyte as soon as possible (within 1 hour) after removal of the transport plugs. The cells should never remain empty when they are not fully discharged, otherwise they will be permanently damaged.
The electrolyte is a solution of potassium hydroxide (KOH) in distilled or demineralised water with an addition of lithium hydroxide (LiOH) and is designed for a use in temperatures of between -25°C and +45°C. The lithium hydroxide in the electrolyte varies between the different cell types (H, M, L). Production of the electrolyte is governed by DIN IEC 993.
When the cells are retracted, the density of the electrolyte is normally 1.19 kg/l ± 0.01 kg/l at the reference temperature of 20° Celsius (electrolyte density may be higher on delivery)
With nickel-cadmium cells, electrolyte density is not an indication of the state of charge. For most FNC products HOPPECKE will supply on request a special electrolyte which allows operation in low temperatures down to -45° Celsius.

Only electrolyte approved and recommended by HOPPECKE should be used. Observe the safety instructions for dealing with electrolyte.
Sulphuric acid should never be used!

Immediately after filling the cells should be closed using the standard vent plugs supplied (hinged lid plugs) or else AquaGen® vent plugs.

Electrolyte residues should be removed without using cleaning agents. We recommend using a damp cloth. Plastic parts of the battery, in particular cell containers, may be cleaned only with water with no additives.

Marking of the battery

Polarity plates must be affixed visibly to the end terminals of the battery. If necessary the cells may be provided with consecutive numbers (from the positive to the negative terminal of the battery) at a clearly visible point.
Since 1.1.97, in accordance with the Low Voltage Directive 73/23/EEC, batteries with a rated voltage in excess of 75 V must be provided with the CE mark. This marking also includes the provision of an EU declaration of conformity. By this declaration the installer confirms that the batteries have been set up in accordance with the applicable standard (DIN EN 50272-2). In general, the fitter is also the installer.

Testing of the battery installation

As a final test of battery installation, the open-circuit voltage of the filled battery must be measured using a suitable voltmeter. The open-circuit voltage of the battery is the total of the individual open-circuit voltages of the cells.

Dangerous contact voltages are possible.

At an electrolyte temperature of 20° Celsius, the cells have a minimum open-circuit voltage of 1.27 V. This measurement may be used to determine whether the polarity of individual cells has been reversed during installation. The measurement can of course only be made with filled cells. If the cells were supplied unfilled and uncharged (UUU), then a 12 hour waiting period should elapse between filling and initial operation.

Further action, in particular bringing the battery into operation for the first time, is described in the instructions "Commissioning of stationary nickel-cadmium batteries with fibre-structured (FNC) electrodes". These instructions are supplied with the battery, and it is essential that they are observed.

Cd

Used batteries with this mark are recyclable goods and must be sent for recycling. Used batteries which are not sent for recycling are to be disposed of as special waste, observing all the applicable regulations. HOPPECKE has a "closed loop recycling system" for NiCd batteries, please contact your local HOPPECKE dealer for any questions according recycling of batteries.

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Commissioning

of stationary Nickel-Cadmium Batteries with FNC cells

It is assumed that only qualified personnel are engaged in assembly and installation of the components provided.

Qualified personnel are persons who, on the strength of their training, experience and instruction, together with their knowledge of the relevant standards, provisions, accident prevention regulations and operating conditions, have been authorised by those responsible for the safety of the components / installation, to carry out the relevant necessary work, with the ability to recognise and avoid possible hazards. Amongst other things, knowledge of First Aid and of local rescue equipment are also necessary.

Failure to observe the instructions on use, repair with non-original parts, unauthorised intervention, or use of additives to the electrolyte shall invalidate the warranty.

1. Safety instructions

The following safety measures relate to the handling of batteries and are to be observed in connection with all operating instructions contained in these instructions.

Observe assembly and installation instructions and display visibly at point of Installation. Work on batteries only after instruction by qualified staff. The operating instructions must always be accessible to personnel responsible for dealing with batteries.

Wear eye protection and protective clothing when working with batteries. Observe accident prevention regulations.

No smoking. No open flame, embers or sparks in the vicinity of the battery, to avoid risk of explosion and fire.

Explosion and fire risk, avoid short-circuits. Warning! Metal parts of the battery cells are always live. Never place foreign objects or tools on the battery. Ensure adequate ventilation of the battery room, so that explosive gases produced during charging are drawn off (see DIN EN 50272-2).

Have eye rinsing bottle to hand. If electrolyte splashes into the eyes or onto the skin, rinse with plenty of clear water and seek immediate medical advice. Clothing contaminated with electrolyte is to be washed thoroughly.

Electrolyte is highly corrosive. In normal operation there is no possibility of contact with the electrolyte. Electrolyte is released only if the cell housing is destroyed.

Do not tilt the battery. Use only approved lifting and conveying equipment e.g. lifting gear. Lifting hooks must not cause damage to cells, connectors or connection cables.

Dangerous electrical voltage. Use only suitable tools and measuring instruments.

NiCd batteries or cells belong to flammability class E (see DIN EN 2). If electrical fires occur, it is possible that the equipment may be live! Extinguishing water or foam are ideal conductors and electric shocks may occur. Electrical fires must be fought with extinguishing powder or carbon dioxide CO_2.

2. First Aid measures

Electrolyte in contact with the eyes:
- Rinse immediately with plenty of water for at least 10 minutes.
- If available, rinse the eyes 1% boric acid solution
- Immediately visit the eye clinic/eye casualty department.

Electrolyte in contact with the skin:
- Immediately remove clothing contaminated by electrolyte, and wash affected areas of skin with plenty of water. Visit doctor if any problems occur.
- Skin which has been in contact with electrolyte has a soapy consistency. Continue rinsing with water until normal skin condition has been restored.

If electrolyte is swallowed:
- Rinse out mouth immediately with plenty of water, and repeatedly drink large amounts of water.

Do not induce vomiting. Call emergency medical service immediately. Any liquid spillage must be analysed for acidity and alkalinity using litmus papers. If the liquid is alkali neutralise with 1% Boric acid solution using half a cupful of Boric acid to 2 gallons of water. Any liquid collected should be kept in a plastic container and disposed of by an Authorised Contractor. Never put it into the sewage system!

3. Transport and storage

Batteries must be packed, marked and conveyed in accordance with the applicable transport regulations (ADR, IMDG Code, IATA). The cells of the battery should be protected against short-circuiting, sliding, falling over or damage and are to be secured to pallets by suitable means. There should be no dangerous traces of lye on the outside of the packages. Any special national regulations are to be observed.

Following receipt and inspection of batteries, the battery cells should be replaced in their original packing. This provides the

battery with good protection against damage while it is in storage prior to installation.

3.1 Tools

At all times insulated tools must be used to prevent the battery from direct short circuits at the cells.
Nickel Cadmium Battery electrolyte should never be allowed to come into contact with lead acid batteries and Sulphuric acid from lead acid batteries should not be used in nickel cadmium batteries. Tools and instructions should be dedicated to one battery or the other, not both. Cross contamination will destroy the batteries. Any liquid spillage from nickel cadmium batteries must immediately be neutralised using half cup of boric acid to 2 gallons of water (or 5% hydrochloric acid solution).
Hydrometers, thermometers and voltmeters for lead acid batteries must be kept separate.

3.2 Transport

For transport the cells are provided with yellow transport plugs before departure from the factory.

In the case of used cells, the standard vent plugs (hinged lid plugs) or AquaGen® plugs are replaced by the yellow transport plugs. The standard vent plugs (hinged lid plugs) or AquaGen® plugs should be kept for possible subsequent use.
- The cells should be transported in an upright position, secured against sliding, tipping over or damage.
- It is essential that the relevant national or international regulations for the transport of dangerous goods are observed.

3.3 Storage

Basically, batteries must be stored on pallets in a dry area, if possible under a dustproof cover.
The recommended storage temperature is 20°C.
- The storage area should satisfy the following requirements:
- The storage space must be dry
- The storage space must be frost-free
- The temperature of the storage area may not exceed 30°C
- The battery must not be subject to any major fluctuations in temperature
- The battery cells may not be stacked
- The battery cells should not be exposed to direct sunlight
- Suitable binding material, a container, and a brush and shovel should be available to deal with any spilt electrolyte.

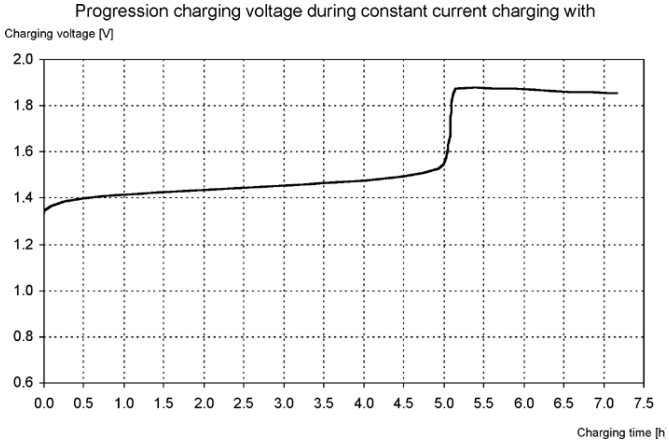
4. General instructions on commissioning of the battery

Both during and after charging, the battery produces explosive detonating gas (a mixture of oxygen and hydrogen). Adequate ventilation must therefore be provided, as specified in DIN EN 50272-2. No electrical connections has to be connect or disconnect up to 1 hour after charging. No naked flame, glowing matter, electrical equipment or carriers of static electricity which could generate sparks are to be allowed in the vicinity of the battery.

Metal parts of the battery can conduct voltage. Use insulated tools and wear suitable clothing! Do not wear rings, watches or metal objects while working on battery installations. The load must be disconnected from the battery. The battery must be connected to the direct current supply with correct polarity (positive terminal to positive terminal connector), with the battery charger switched off and the load disconnected.

4.1 I and Ia charging

Charging with constant current is used particularly for NiCd and NiMH batteries. An advantage is that the amount charged can be determined directly from charging time. With a higher charging current, the charging time may be reduced accordingly. If a charging method without a cut-off value (I charging) is used then, on reaching a state of full charge, the battery will be overcharged. The entire charging current then goes into secondary reactions. The diagram below shows the charge voltage depending on time during charge with constant current I_5.



In principle, HOPPECKE recommend commissioning at constant current I_5 for all NiCd cells, but commissioning with constant voltage is also possible. The state of full charge of an alkaline battery is clearly recognisable from a rise in voltage. During initial charging with constant current, cell voltages up to 1.9 V may occur. The charging method used in commissioning must allow for this and, where necessary, the battery should be split for this purpose.
If the charging method does not allow the individual cells to be supplied with at least 1.9 V, then the charging time should be suitably extended. When charged and filled cells are supplied, a certain amount of self-discharge occurs, which is swiftly compensated for after commissioning. Since in this case the negative electrode is at a high state of charge, even commissioning at a limited voltage of at least 1.65 V per cell will lead to an evenly charged battery.

4.2 U and IU charging

Charging with constant voltage leads to a falling current. This is due to the rise in the open-circuit voltage and the internal resistance as the state of charge increases. The high charging current at the start of charging may be a problem. For this reason, charging methods involving only U charging are not used. The IU charging procedure is used, in which the current is limited to a maximum value.

An advantage of IU charging is that batteries may be connected in parallel with no problems (parallel charging), and that overcharging is minimal (if the correct charging voltage is chosen). Against this is the fact that a much longer charging time is required to reach a state of full charge.

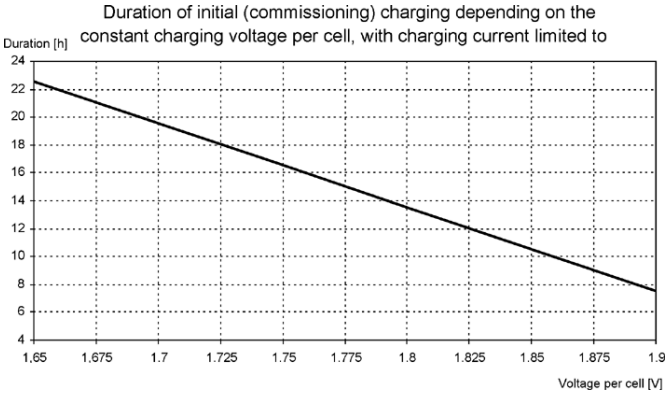
Under charging with constant current, the current must be limited to the five-hour discharge current I_5 (e.g. for a 100 Ah battery the current I_5 = 20 A). In the case of initial charging at a constant limited voltage of 1.65 V per cell and a current limited to I_5, the charging time must be extended. Full charge of the negative electrode, which normally limits the charging process, may be recognised from a voltage rise accompanied by a simultaneously fall in the current. Since, however, the current does

not fall to zero, a further equalising charge off the positive electrode occurs. Only when the positive electrode is also fully charged does the user have the full capacity of the cell at their disposal.

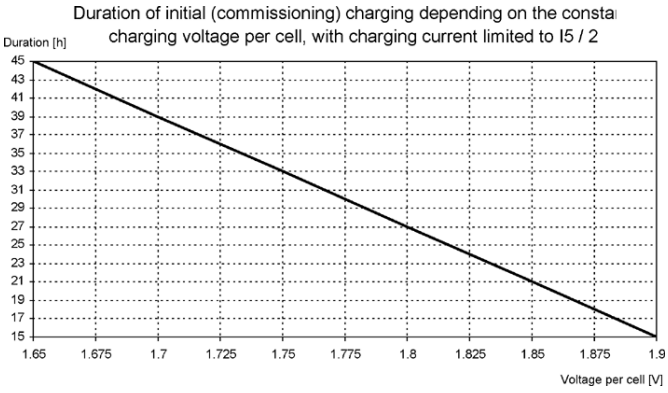
The following table shows the specified charging time for initial charging with limitation of charging voltage:

Voltage [V]	Time [h]	Current [A]	Capacity [Ah]	Descpription
1.9/cell	7.5	I_5	1.5 * Cn	Recommended method: the product of current and time with a cell voltage of 1.9 V should correspond to 1.5 * Cn. Example 100 Ah cell 1.9 V cell voltage: I = 20 A T = (100 Ah / 20 A) * 1.5 = 7.5 h
1,85/cell 1,8/cell 1,75/cell 1,7/cell 1,65/cell	10.5 13.5 16.5 19.5 22.5	I_5	1.5 * Cn	In limiting the charging voltage an additional factor must be introduced. If starting from 1.9 V per cell the voltage is reduced by 0.5 V, then charging time must be increased by 3 hours in each case. Charging voltages of less than 1.65 V per cell are not allowed.

If charging voltage is limited, then charging time must be altered accordingly. The following diagram shows the duration of initial charging at constant voltage at a charging current limited to I_5.



If now the current is also limited, then charging time must be further extended. For a battery charged with a limitation of cell voltage to 1.8 V per cell and a current of I_5, then 13.5 hours will be required to obtain a good result. If the current is halved, then the charging time must be doubled.



The charging voltage for initial charging should lie between 1.65 and 1.9 V. Acceptable values for current are between $I_5/2$ and I_5.
Satisfactory results will not be obtained with values lying outside these ranges.

The duration of initial charging may be calculated as follows:
Assumption: 100 Ah FNC cell
I_5 = Cn / 5h
100 Ah / 5h = 20 A

$T_{opt.}$ = (1.5 * Cn) / I_5 at 1.9 V/cell
(1.5 * 100 Ah) / 20 A = 7.5 h

Ia Initial charging
Optimal commissioning charge: constant current = 20 A over 7.5 h with limited cell voltage = 1.9 V

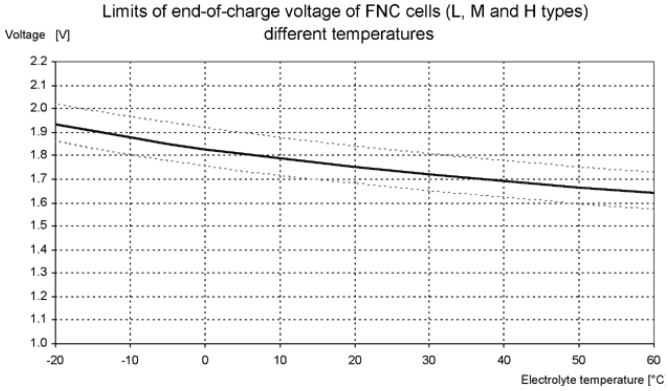
Assumption: a constant voltage of 1.7 V is available
T_{IBL} = $T_{opt.}$ + (1.9 V – 1.7 V) * (3 h / 0.5 V)
7.5 h + 12 h = 19.5 h

IU Initial charging
Possible commissioning charge: constant cell voltage = 1.7 V over 19.5 h with limited current = 20 A

Assumption: In addition the battery charger can only supply 15 A
T_{IBL1} = T_{IBL} * (I_5 / I_{actual})
19.5 h * (20 A / 15 A) = 26 h

IU Initial charging
Possible commissioning charge: constant cell voltage = 1.7 V over 26 h with limited current = 15 A

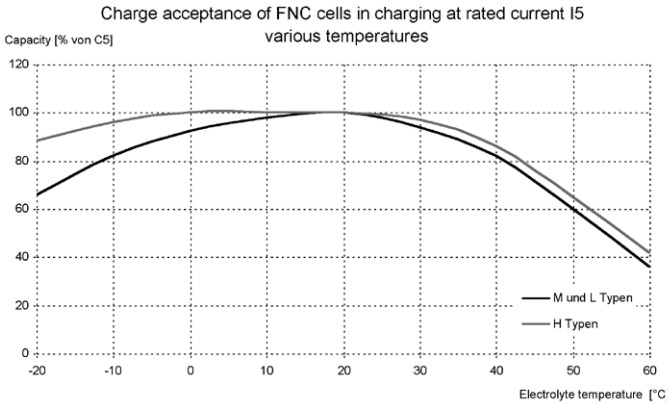
If charging takes place at a constant rated current I5 and without voltage limitation over a period of more than 5 h, then the individual cells will reach a voltage which will not increase further even with additional charging. This is the so-called end-of-charge voltage, which depends on the electrolyte temperature. This relationship is shown in the following diagram:



The end-of-charge voltage shown on this graph may vary by ± 5% between individual cells.

If an electrolyte temperature of +45°C is exceeded, then charging should be interrupted and the battery allowed to cool down.

The capacity charged to and withdrawn from a battery also depends on the electrolyte temperature. This relationship is shown in the following diagram:



If batteries with cells of type L are correctly charged at an electrolyte temperature of -20°C, then only 66% of the rated C_n can be fed into the battery. These cells also display the same behaviour at higher temperatures: at 45°C the battery can be charged to only 70% of rated capacity C_n.

During storage, batteries undergo temperature-related self-discharge. This means that the greater the difference between actual and recommended storage temperature, the greater the self-discharge as storage time progresses. If no initial charge is given, then less than the full battery charge will be available at the start of operation.

The age of the cells of a battery may be determined by the date of manufacture, which is stamped into the cell cover in code form. Commissioning will follow a different course depending on the condition and age of the cells supplied.

Cell cover stamp on HOPPECKE FNC cells (FNC 411 L as example):

L11	21	02

- 02 — Year of manufacture, in this case 2002
- 21 — Week of manufacture in the year, here calendar week 21
- L11 — Type of cell, here 11 plate pairs of performance type L

4.3 Commissioning of the battery after a short period of storage or transport

Before charging, remove any yellow transport plugs still in place. This is necessary to avoid any build-up of pressure in the cells, as result of water decomposing during charging. In principle, care is to be taken that no contaminants of any kind gain access to the opened cells. During any waiting period, the cells should be closed by a plug (standard vent plug or transport plug). During charging these plugs are to be removed since during initial charging, entrained electrolyte droplets contaminate both the hinged lid plugs and also the Aqua-Gen® vent plugs. No other work of any kind should be carried out in the battery room during bringing into operation of the battery.

In principle, before the start of commissioning, check the recommended settings for the battery charger and ensure that it is functioning properly.

4.3.1 Battery comprised of unfilled and uncharged cells

- Ensure that you have the electrolyte specified for the particular type of cell. The electrolyte is different for each of the performance types (H, M and L types).
- Only remove the yellow transport plugs fitted by the manufacturer just before (maximum 10 minutes) filling the cells with electrolyte.
- The transport plugs should be kept for subsequent use.
- The cells are filled with the specified electrolyte (aqueous potassium hydroxide solution with an addition of lithium hydroxide) up to the min. mark + 1 cm. Slight heating may occur during filling. Any splashes of lye should be removed with a damp cloth.
- Close the cells with a vent plug.
- After the cells have been filled, initial charging may commence only after a waiting time of 12 hours.
- The plugs used for the waiting period must be removed.

- Initial charging is given at a constant rated current I5 over a period of 7.5 h, i.e. the battery is charged at a charge factor of 1.5. If a lower current is used, then the charging time should be extended accordingly. At least 50% of the rated current I5 should be charged during the initial charging. If charging has to be interrupted (e.g. electrolyte temperature > 45°C) it must be ensured that a charge factor of 1.5 is reached.
- After a waiting period of at least 2 hours, top up with electrolyte to the maximum mark.
- The cells are sealed using the standard vent plugs (hinged lid plugs) or AquaGen® vent plugs supplied
- The cells should be cleaned.

These cells may be brought into operation only with constant current in accordance with the Ia charging characteristic. A commissioning charge based on U or IU charging is not permissible.

4.3.2 Battery comprised of filled and charged cells

- Before charging, remove any yellow transport plugs still in place.
- The transport plugs should be kept for subsequent use.
- Initial charging is given at a constant rated current I_5 over a period of 7.5 h, i.e. the battery is charged at a charge factor of 1.5. If a lower current is used, then the charging time should be extended accordingly. At least 50% of the rated current I_5 should be charged during the initial charging. If charging has to be interrupted (e.g. electrolyte temperature > 45°C) it must be ensured that a charge factor of 1.5 is reached. If charging voltage or charging current are limited, then the charging time must be extended accordingly. The charging voltage may not be limited to less than 1.65 V per cell.
- After a waiting period of at least 2 hours, top up the electrolyte with distilled or de-ionised water (no water containing acid!) to the maximum mark.
- The cells are sealed using the standard vent plugs (hinged lid plugs) or AquaGen® vent plugs supplied.
- The cells should be cleaned.

4.4 Commissioning of the battery after storage for over 12 months

Before commissioning, cells which have been stored for a long time should be checked for any damage, and also to confirm that all accessories are present (in particular standard or AquaGen® vent plugs).

For the correct commissioning of batteries after a lengthy period of storage, it is necessary to use a suitable charge/discharge unit.

4.4.1 Battery comprised of unfilled and uncharged cells

Unfilled and uncharged cells have a virtually unlimited shelf life. These batteries are commissioned in accordance with the instructions above for "Commissioning of the battery after a short period of storage or transport" for batteries comprised of unfilled and uncharged cells.

4.4.2 Battery comprised of filled and charged cells

In principle, batteries made up of cells which have been in store for a longer period of time are brought into operation in the same way as batteries comprising cells stored for short periods of time.

- These batteries are commissioned in accordance with the instructions above for "Commissioning of the battery after a short period of storage or transport" for batteries comprised of filled and charged cells.

The battery should then be additionally charged and discharged (a maximum of 3 charge/discharge cycles).

- Discharge is at the rated current I_5 down to a voltage of 1.0 V per cell on an arithmetical average.
- The cell plugs are removed.
- Initial charging is given at a constant rated current I_5 over a period of 7.5 h, i.e. the battery is charged at a charge factor of 1.5. If a lower current is used, then the charging time should be extended accordingly. At least 50% of the rated current I5 should be charged during the initial charging. If charging has to be interrupted (e.g. electrolyte temperature > 45°C) it must be ensured that a charge factor of 1.5 is reached. The charging voltage may not be limited to less than 1.65 V per cell.
- A pause of 30 minutes should be made between each instance of charging and discharge, so that the gases formed by the decomposition of water may bubble up.

On completion of final charging and after a waiting time of at least 2 hours, the electrolyte level is topped up to the maximum mark with distilled or de-ionised water (no water containing acid!).

- The cells are then sealed using the standard vent plugs (hinged lid plugs) or AquaGen® vent plugs supplied.
- The cells should be cleaned.

5. Capacity testing of batteries in accordance with DIN IEC 623

The battery should be given a capacity test every 3-5 years. This is especially important after the commissioning of batteries after a long period of storage, so that the end of battery life may be forecast accurately.

In accordance with international standard DIN IEC 623, charging takes place at constant rated current I_5 over a period of 7 to 8 hours. After charging the battery should be stored for a minimum of 1 h but for no more than 4 h at an ambient temperature of (20 ± 5)°C. Discharge is effected at rated current I5 down to a voltage of 1.0 V per cell as an arithmetical average. To obtain a capacity of 100%, the minimum discharge time should be 5 h.
The capacity obtained during this test may be calculated as follows: Capacity (%) = (discharge time (h) / 5 h) * 100

If after five charge/discharge cycles the capacity required for this test has not been reached, then the battery should be replaced.

To carry out a capacity test on the battery, proceed as follows:

1. Discharge at rated current I_5 down to a voltage of 1.0 V per cell on an arithmetical average.
2. Pause for at least 8 hours. During this waiting period, the cells must be sealed by vent plugs (transport, standard or AquaGen® vent plugs).
3. Charge at constant rated current I_5 over a period of 7.5 h, with vent plugs (standard or AquaGen® vent plugs) removed.
4. 2-hour pause, during which the cells must be sealed by vent plugs (transport or standard vent plugs).
5. Discharge at rated current I_5 down to a voltage of 1.0 V per cell on an arithmetical average. This discharge completes the capacity test as specified in DIN IEC 623.

If insufficient capacity is determined in the capacity test under point 5 above, then points 2 to 5 should be repeated until capacity no longer rises.

After this capacity test, the following work is necessary for correct operation of the battery:

- Pause for at least 8 hours. During this waiting period, the cells must be sealed by vent plugs (transport, standard or AquaGen® vent plugs).
- Charge at constant rated current I_5 over a period of 7.5 h, with vent plugs (standard or AquaGen® vent plugs) removed.
- On completion of charging, the cells are sealed using the standard vent plugs (hinged lid plugs) or AquaGenh vent plugs supplied
- After a waiting period of at least 2 hours, top up the electrolyte with distilled or de-ionised water (no water containing acid!) to the maximum mark.
- The cells should be cleaned.

6. Cleaning of the battery

A clean battery is essential, not only for the sake of external appearance, but more importantly to avoid accidents and material damage, together with any reduction in the life expectancy and availability of the battery. It is necessary to clean the cells, racks and insulators in order to maintain the required insulation of the cells from earth or from external conductive parts. This will also avoid damage due to corrosion and leakage currents. Regular cleaning of the battery is necessary not only to secure its high availability, but as an important element in the observance of accident prevention regulations.

Dangerous contact voltages are possible. Observe the notes on safety in these operating instructions.

During initial charging and in operation, the evaporation of entrained electrolyte droplets during water decomposition may lead to the deposition of white electrolyte residues on the cells. These residues should be removed without the use of cleaning agents, with the standard vent plugs (hinged lid plugs) removed. We recommend the use of a damp cloth.

- Plastic parts of the battery, in particular cell containers, may only be cleaned with water with added rinsing agent. With the transport plugs fitted, the battery may be cleaned using a high-pressure cleaner. The pressure must be set so that the plastic parts are not damaged (cleaning temperature should not exceed 60°C with a max. operating pressure of 50 bar).
- Standard vent plugs (hinged lid vent plugs) may be cleaned in a bucket with rinsing agent. The plugs should then be dried thoroughly.
- Avoid electrostatic charging (do not use dry cloths for cleaning!).

7. Electrolyte

As the charge exchange medium, the electrolyte is of critical importance, ensuring optimal performance of the battery when kept at the correct concentration and filling level. There will be a loss of performance if electrolyte levels are too low. Special attention should therefore be given during maintenance to ensuring that electrolyte levels are correct. The electrolyte is comprised of aqueous potassium hydroxide solution (KOH) with an addition of lithium hydroxide (LiOH), and is designed for use in temperatures ranging from -25 to +45°C. DIN IEC 993 applies to the production of the electrolyte. When the cells have been in use for some time the density of the electrolyte is usually 1.19 kg/l-1 ± 0.01 kg/l-1 at the reference temperature of 20° Celsius (on delivery the electrolyte density may be higher). The electrolyte density is temperature-dependent and may be adjusted using the correction factor 0.0005 kg/l-1 K-1. The lithium hydroxide (LiOH) content varies for each of the different load types L, M and H. The electrolyte retains its effectiveness throughout the entire life of the battery and does not need to be replaced. In nickel-cadmium cells, electrolyte density does not give an indication of the state of charge.

For the majority of FNC products HOPPECKE will provide on request a special electrolyte allowing operation even in the temperature range down to -45ºC.

8. Documentation

A record should be made during commissioning of the battery. A form for such a commissioning record is appended to these instructions. If your battery has more cells than provided for on the form, please ask HOPPECKE Batterie Systeme for a suitable form for your purposes.

9. Taking the battery out of service

- Discharge at rated current I5 down to a voltage of 1.0 V per cell.
- Replace the standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs by the yellow transport plugs. This is important to avoid atmospheric oxygen coming into contact with the electrodes.
- Clean the battery including all cells
- Store on pallets in a dry, frost-free room. The complete battery or the individual cells should be provided with a cover.

In principle, when taking the battery out of service, the standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs on the individual cells should be replaced by the yellow transport plugs. The standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs should be kept for subsequent use.

Depending on the length of storage after being taken out of service, the battery should be brought back into service again in accordance with these instructions.

9.1 Disposal

Disassembly and disposal of the battery should be carried out only by trained personnel. EC Directives 91156 (EEC) and 9386 (EEC) must be observed. Your local HOPPECKE representative will be pleased to give you a quotation for proper disassembly and disposal of your battery. To take back all no longer used batteries, is the long term target of the HOPPECKE collection and recycling concept.

We have entered into a cooperation contract with two companies to use there logistic network of collection points for Europe. Both recycler separate the cadmium content of the batteries by distillation. This cadmium will be used for the production of cadmium oxide for new batteries. This is the great advantage of these method. In this way we have a "Closed Loop System" for the cadmium content of the recycled batteries.

Further action, in particular the operation and maintenance of the battery, is described in the instructions "Operation and maintenance of stationary nickel-cadmium batteries with FNC cells". It is essential that these instructions, which are supplied with the battery, are followed.

Cd

Used batteries with this symbol are recyclable goods and must be sent for recycling. Used batteries which are not sent for recycling are to be disposed of as special waste under the appropriate regulations. Hoppecke have a "closed loop" recycling system for NiCd batteries. Your local HOPPECKE representative will be pleased to give you a quotation for disposal of your battery.

10. Commissioning record for | FNC NiCd batteries

Customer: _____ Order No.: _____

Where installed: _____

_____

_____

_____

_____

Supplier: _____

Battery No.: _____

Cell type: _____ No. of cells: _____

Capacity [Ah]: _____

Charging method:

❍ Constant voltage (U- or IU characteristic)

Constant voltage [V]: _____

Maximum current [A]: _____

❍ Constant current (I or Ia characteristic)

Constant current [A]: _____

Maximum voltage [V]: _____

Battery voltages:

Charging voltage [V] Start of charging: _____ end of charging: _____

Open-circuit voltage [V] Start of charging: _____ end of charging: _____

Charging current:

Charger current [A] Start of charging: _____ end of charging: _____

Temperatures:

Ambient [°C] Start of charging: _____ end of charging: _____

Electrolyte [°C] Start of charging: _____ end of charging: _____

Pilot cell [°C] Cell-No.: _____

Charging time:

Date from: _____ to: _____

Time from: _____ hours to: _____ hours

Commissioning carried out by: Date, signature _____

Acceptance (supplier) carried out by: Date, signature _____

Acceptance (customer) carried out by: Date, signature

Measurement of individual cell voltages 1-120:

Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]
1				41				81			
2				42				82			
3				43				83			
4				44				84			
5				45				85			
6				46				86			
7				47				87			
8				48				88			
9				49				89			
10				50				90			
11				51				91			
12				52				92			
13				53				93			
14				54				94			
15				55				95			
16				56				96			
17				57				97			
18				58				98			
19				59				99			
20				60				100			
21				61				101			
22				62				102			
23				63				103			
24				64				104			
25				65				105			
26				66				106			
27				67				107			
28				68				108			
29				69				109			
30				70				110			
31				71				111			
32				72				112			
33				73				113			
34				74				114			
35				75				115			
36				76				116			
37				77				117			
38				78				118			
39				79				119			
40				80				120			

1* = open terminal voltage · 2* = end-of-charge voltage 15 min before end of charging · 3* = cut-off voltage after 5 hours discharge

Measurement of individual cell voltages 121-240:

Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]
121				161				201			
122				162				202			
123				163				203			
124				164				204			
125				165				205			
126				166				206			
127				167				207			
128				168				208			
129				169				209			
130				170				210			
131				171				211			
132				172				212			
133				173				213			
134				174				214			
135				175				215			
136				176				216			
137				177				217			
138				178				218			
139				179				219			
140				180				220			
141				181				221			
142				182				222			
143				183				223			
144				184				224			
145				185				225			
16				186				226			
147				187				227			
148				188				228			
149				189				229			
150				190				230			
151				191				231			
152				192				232			
153				193				233			
154				194				234			
155				195				235			
156				196				236			
157				197				237			
158				198				238			
159				199				239			
160				200				240			

1* = open terminal voltage · 2* = end-of-charge voltage 15 min before end of charging · 3* = cut-off voltage after 5 hours discharge

Measurement of individual cell voltages 241-360:

Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]	Cell No.	1* [V]	2* [V]	3* [V]
241				281				321			
242				282				322			
243				283				323			
244				284				324			
245				285				325			
246				286				326			
247				287				327			
248				288				328			
249				289				329			
250				290				330			
251				291				331			
252				292				332			
253				293				333			
254				294				334			
255				295				335			
256				296				336			
257				297				337			
258				298				338			
259				299				339			
260				300				340			
261				301				341			
262				302				342			
263				303				343			
264				304				344			
265				305				345			
266				306				346			
267				307				347			
268				308				348			
269				309				349			
270				310				350			
271				311				351			
272				312				352			
273				313				353			
274				314				354			
275				315				355			
276				316				356			
277				317				357			
278				318				358			
279				319				359			
280				320				360			

1* = open terminal voltage · 2* = end-of-charge voltage 15 min before end of charging · 3* = cut-off voltage after 5 hours discharge

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Operation and Maintenance

of stationary Nickel-Cadmium Batteries with FNC cells

It is assumed that only qualified personnel are engaged in assembly and installation of the components provided. Qualified personnel are persons who, on the strength of their training, experience and instruction, together with their knowledge of the relevant standards, provisions, accident prevention regulations and operating conditions, have been authorised by those responsible for the safety of the components / installation, to carry out the relevant necessary work, with the ability to recognise and avoid possible hazards. Amongst other things, knowledge of First Aid and of local rescue equipment are also necessary.

Failure to observe the instructions on use, repair with non-original parts, unauthorised intervention, or use of additives to the electrolyte shall invalidate the warranty.

1. Safety instructions

The following safety measures relate to the handling of batteries and are to be observed in connection with all operating instructions contained in these instructions.

Observe assembly and installation instructions and display visibly at point of installation.
Work on batteries only after instruction by qualified staff. The operating instructions must always be accessible to personnel responsible for dealing with batteries.

Wear eye protection and protective clothing when working with batteries.
Observe accident prevention regulations.

No smoking. No open flame, embers or sparks in the vicinity of the battery, to avoid risk of explosion and fire.

Explosion and fire risk, avoid short-circuits. Warning! Metal parts of the battery cells are always live. Never place foreign objects or tools on the battery. Ensure adequate ventilation of the battery room, so that explosive gases produced during charging are drawn off (see DIN EN 50272-2).

Have eye rinsing bottle to hand. If electrolyte splashes into the eyes or onto the skin, rinse with plenty of clear water and seek immediate medical advice.
Clothing contaminated with electrolyte is to be washed thoroughly.

Electrolyte is highly corrosive. In normal operation there is no possibility of contact with the electrolyte. Electrolyte is released only if the cell housing is destroyed.

Do not tilt the battery!
Use only approved lifting and conveying equipment e.g. lifting gear. Lifting hooks must not cause damage to cells, connectors or connection cables.

Dangerous electrical voltage. Use only suitable tools and measuring instruments.

NiCd batteries or cells belong to flammability class E (see DIN EN 2). If electrical fires occur, it is possible that the equipment may be live! Extinguishing water or foam are ideal conductors and electric shocks may occur. Electrical fires must be fought with extinguishing powder or carbon dioxide CO_2.

2. First Aid measures

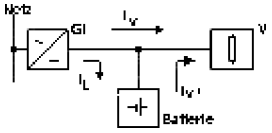
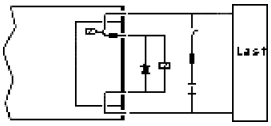
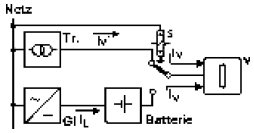
Electrolyte in contact with the eyes:
- Rinse immediately with plenty of water for at least 10 minutes.
- If available, rinse the eyes 1% boric acid solution
- Immediately visit the eye clinic/eye casualty department.

Electrolyte in contact with the skin:
- Immediately remove clothing contaminated by electrolyte, and wash affected areas of skin with plenty of water. Visit doctor if any problems occur.
- Skin which has been in contact with electrolyte has a soapy consistency. Continue rinsing with water until normal skin condition has been restored.

If electrolyte is swallowed:
- Rinse out mouth immediately with plenty of water, and repeatedly drink large amounts of water.

Do not induce vomiting. Call emergency medical service immediately. Any liquid spillage must be analysed for acidity and alkalinity using litmus papers. If the liquid is alkali neutralise with 1% Boric acid solution using half a cupful of Boric acid to 2 gallons of water. Any liquid collected should be kept in a plastic container and disposed of by an Authorised Contractor. Never put it into the sewage system!

3. Operating modes

Operating mode	Characterisation	Charging voltage	Characteristic
Standby parallel operation 	Load, direct current source and battery are constantly connected in parallel.	1.40 – 1.45 V/cell charge retention 1.55 – 1.65 V/cell boost charge after 7.5 h switch to charge retention	IU
Float operation 	Load, direct current source and battery are connected in parallel, with the direct current source supplying only the average load current and the battery covering the peak current demands.	1.45 – 1.50 V/cell	IU
Switching operation 	During charging, the battery is disconnected from the load.	1.40 – 1.45 V/cell charge retention 1.55 – 1.65 V/cell boost charge charge monitoring necessary safe cut-off criterion required up to 1.9 V/cell.	IU

All voltages shown are based on 20° Celsius. The charging voltages shown are temperature dependent and must be adjusted by the temperature correction factor of -2 mV/°K up to -3 mV/°K per cell for higher temperatures.

4. Maintenance

Correct maintenance of the battery system and its components is a basic requirement to ensure a satisfactory service life of the battery. This maintenance covers two aspects, on the one hand preventive maintenance and on the other hand corrective maintenance. If during preventive maintenance a deficiency is discovered, then this is rectified during corrective maintenance.

4.1 Preventive maintenance

To ensure that your battery remains in optimum condition, we recommend the following maintenance programme.
It is also recommended that maintenance records are kept, to include details of the temperature in the room in which the batteries are installed or they are stored.

Preventive Maintenance Table:

Activity	Frequency	Tool / Material (references)
Visual inspection of the battery	every 6 months	(see „Cleanliness / physical condition “)
Check electrolyte level	every 6 months	(see „Measurement of electrolyte levels“)
Measure overall battery voltage	every 6 months	Tool: G02 Voltmeter (see „Checking of individual and overall voltages“)
Clean battery	every 12 months	(see „Cleaning“)
Measure individual cell voltage of all cells	every 5 years	Tool: G02 Voltmeter, G07 Thermometer (see „ Checking of individual and overall voltages“)
Capacity test	every 5 years	Tool: G02 Voltmeter ,G04 External charging and discharge unit, G07 Thermometer (see „Capacity test“)

4.1.1 Cleanliness/physical condition

A clean battery is vitally important, not only for the sake of appearance but, more importantly, to avoid accidents and material damage, together with reduced life and availability of the battery. The cleaning of cells and battery racks is necessary to maintain the required insulation of the cells from earth or from external conductive components. Damage due to corrosion and leakage currents can also be avoided by cleaning. Regular cleaning of the battery is not only necessary to secure high availability but is also an important element in the observance of accident prevention regulations.

Dangerous contact voltages are possible.
The hazard warnings of these operating instructions must be observed.

During initial charging and in operation, the evaporation of entrained electrolyte droplets during water decomposition may lead to the deposition of white electrolyte residues on the cells. These residues should be removed without the use of cleaning agents. We recommend the use of a damp cloth.

- Plastic parts of the battery, in particular cell containers, may only be cleaned with water with added rinsing agent. With the transport plugs fitted, the battery may be cleaned using a high-pressure cleaner. The pressure must be set so that the plastic parts are not damaged

- Avoid electrostatic charging (do not use dry cloths for cleaning!).

The screws and nuts for the terminal posts must be tightened correctly. To prevent corrosion, a thin layer of neutral Vaseline or anti-corrosion oil should be applied to connection elements and cable eyes.

Screw size	Insulated screw	Non-Insulated screw
M8	16 Nm ± 1 Nm	20 Nm ± 1 Nm
M10	20 Nm ± 1 Nm	25 Nm ± 1 Nm

The enclosed washers insure the correct tightness.
Washers may be used only once. For a new connection a new washers must be used.

4.1.2 Measurement of electrolyte levels

During charging, electrolysis splits the water of the electrolyte into the gases $2H_2 + O_2$. This leads to a lowering of the electrolyte level. The volume of decomposed water depends on charging voltage, charging time per day and temperature. During the first phase of operation, electrolyte levels should be measured and recorded approximately every 3 months. After 12 months, the empirical values thus obtained give sufficient information to determine further monitoring intervals.

This maintenance interval may be doubled by the use of HOPPECKE AquaGen® vent plugs. The cells have polypropylene containers, through the sides of which the electrolyte levels may be read.

4.1.3 Checking of individual or overall voltages

In checking voltages, a distinction is made between individual cell voltages and the overall battery voltage, also between charging and open-circuit voltage. Measurement of the individual voltages is described below. Charging voltage is measured with a suitable voltmeter.

- Remove battery connections.

- Attach the measuring tips of a multi meter to the measuring contacts of the cell screw connector.

• Measure and record the voltage of the cells in turn.

• Mark cells where voltage varies by more than ± 20 mV from the average of all cell voltages.

• Reconnect the battery

In fully-charged condition, the open-circuit voltage should be 1.27 V per cell. These values relate to a temperature of 20°C; consult HOPPECKE if there are extreme variations. Temperatures deviating from 20°C affect these values. Charging voltage should be checked not later than every 6 months. If higher water consumption is detected, then charging voltage is the first factor to be checked.

4.1.4 Test of insulation resistance

DIN VDE 0510 Part 2 stipulates that the insulation resistance of a battery must not fall below the value of 100 Ω per volt of rated voltage. In new condition the insulation resistance is > 1MΩ. The insulation resistance falls over its service life due to aerosols escaping from the battery and because of dust.
An insulation tester with 1500 volts test voltage should be used. The positive terminal and the negative terminal of the battery should each be measured against the metal parts of the rollers.

• The actual setting value should be determined empirically. If insulation faults occur, first disconnect the battery and test the remainder of the electrical installation.

• If higher test voltages are prescribed for other electrical loads then in every case the battery should be disconnected from the onboard system during these tests.

4.1.5 Capacity testing of batteries in accordance with DIN IEC 623

The battery should be given a capacity test every 3-5 years. This is especially important after the commissioning of batteries after a long period of storage, so that the end of battery life may be forecasted accurately. In accordance with international standard DIN IEC 623, charging takes place at constant rated current I_5 (rated capacity C_5 / 5h) over a period of 7 to 8 hours. After charging the battery should be stored for a minimum of 1 h but for no more than 4 h at an ambient temperature of (20 ± 5)°C. Discharge is effected at rated current I_5 down to a voltage of 1.0 V per cell as an arithmetical average. To obtain a capacity of 100%, the minimum discharge time should be 5 h.

The capacity obtained during this test may be calculated as follows:

Capacity (%) = (discharge time (h) / 5 h) * 100

If after five charge/discharge cycles the capacity required for this test has not been reached, then the battery should be replaced.

To carry out a capacity test on the battery, proceed as follows:

1. Discharge at rated current I_5 down to a voltage of 1.0 V per cell on an arithmetical average.

2. Rest for at least 8 hours. During this waiting period, the cells must be sealed by standard or AquaGen® vent plugs.

3. Charge at constant rated current I_5 over a period of 7.5 h, with vent plugs removed.

4. 2-hour rest, during which the cells must be sealed by vent plugs (standard or AquaGen® vent plugs).

5. Discharge at rated current I_5 down to a voltage of 1.0 V per cell on an arithmetical average. This discharge completes the capacity test as specified in DIN IEC 623.

If insufficient capacity is determined in the capacity test under point 5 above, then points 2 to 5 should be repeated until capacity no longer rises.

After this capacity test, the following work is necessary for correct operation of the battery:

• Rest for at least 8 hours. During this waiting period, the cells must be sealed by vent plugs (standard or AquaGen® vent plugs).

• Charge at constant rated current I5 over a period of 7.5 h, with vent plugs removed.

• On completion of charging, the cells are sealed using standard or AquaGen® vent plugs.

• After a waiting period of at least 2 hours, top up the electrolyte with distilled or de-ionised water (no water containing acid!) to the maximum mark.

The capacity test forms part of reconditioning charging. If after several attempts at reconditioning the result of capacity testing is not satisfactory, then the battery has reached the end of its life.

4.1.6 Cleaning

A clean battery is absolutely essential to avoid accidents and material damage, also to maximise battery life and availability. It is necessary to clean cell holders, trays, racks and insulators in order to maintain the required insulation of the cells from one another, from earth, or from external conductive parts. Cleaning also prevents damage from corrosion and leakage current.
DIN VDE 0510 Part 2 specifies that the insulation resistance shall not fall below a value of 100 Ω per volt of cell voltage.
Depending on the location and duration of usage it is impossible to avoid deposits of dust on the battery. Small amounts of electrolyte particles which escape during battery charging above the gassing voltage form a more or less conductive layer on the cells or the block lids. So-called leakage currents then flow through this layer. This results in enhanced and varying self-discharge of the individual cells.
If higher leakage currents flow, then electrical sparks can not be ruled out. Such sparks may cause an explosion of the charging gas (detonating gas) escaping from the cell plugs.
Consequently the cleaning of batteries is necessary not only to ensure high availability, but also as an essential part of accident prevention.

It is essential that the following instructions are followed when cleaning batteries in installed condition:

• The cell plugs must not be removed or opened. Instead, the cells must remain closed.

• Plastic parts of the battery, in particular the cell containers, may be cleaned only with water or with cleaning cloths soaked in water without additives.

• After cleaning, dry the battery surface by suitable means, e.g. compressed air or cleaning cloths.

• Any fluid which has entered the battery tray must be siphoned off, and disposed of in accordance with the regulations governing waste and residues.

4.2 Corrective maintenance

Corrective maintenance table:

Activity	Frequency	Tools / Material (references)
Top up with distilled water	every 6-12 months	Tool: G06 Funnel Material: Distilled water (see „Topping-up the electrolyte“)
Reconditioning charge	every 5 years	Tool: G02 Voltmeter ,G04 External Charging and Discharge unit, G07 Thermometer (see „Capacity test“, „Reconditioning of the battery“)

4.2.1 Topping-up the electrolyte with distilled water

Nickel-cadmium batteries are filled with highly caustic potassium hydroxide solution (KOH) and an additive of lithium-hydroxide (LiOH) in accordance with DIN 43530. When working with the batteries, protective clothing such as rubber gloves and eye protection must be worn. If nevertheless electrolyte comes into contact with skin or eyes, then the latter should be rinsed immediately under running water, after which medical advice should be sought without delay.

If the electrolyte levels of the battery are below the mid-point between the min. and max. marks, the should be topped-up to the max. mark with distilled water.

Any splashes of electrolyte or water should be removed with a damp cloth. The fibre-structure technology allows the use of pure active materials. Additives such as graphite to increase the conductivity of the positive electrodes are no longer necessary. Any carbonisation of the potassium hydroxide solution due to the electrodes is therefore ruled out.

No change of electrolyte is necessary during the entire life of the battery.

4.2.2 Reconditioning the battery

The decline in the state of charge of a battery can be reversed only by charging at constant current. This is described as reconditioning of the battery. In order to carry out this reconditioning , the battery must be charged and discharged in a defined manner. Before this charging, the battery should be disconnected from the onboard system, since during reconditioning of the battery with constant current, cell voltages of up to 1.9 V may occur. Also during this charging, a larger amount of water is decomposed than during normal operation, so that provision for adequate ventilation must be ensured, in accordance with DIN VDE 0510.

The following discharge/charging procedure is recommended:

1. Discharge the battery at I5 down to 1.00 volt/cell on the arithmetic average.

2. Rest > 8 hours, if possible overnight

3. Charge at constant current I_5 over 7.5 hours

4. Rest for 2 hours

5. Discharge at I_5 down to 1.0 volt per cell on the arithmetic average (capacity test)

6. Rest > 8 hours, if possible overnight

7. Charge at constant current I_5 over 7.5 hours

If the capacity test reveals insufficient capacity then the tests covered by points 1 to 5 above are to be repeated until capacity no longer rises. The same criteria also apply to capacity tests.

5. Fault-finding

5.1 Excessive water consumption

Loss of water occurs on the one hand due to evaporation, but also due to the decomposing of the water into oxygen and hydrogen gas during charging. The first thing to check is the charging voltage in the system. If this is correct, then proceed as follows:

- Measure the individual cell voltages during charging
  If the individual cell voltages vary by more than ± 50 mV from the average, then the battery should be removed, and the following measurement undertaken after 2 days' rest:

- Measure the open-circuit voltage after 2 days' rest
  If individual cell voltages vary by more than ± 20 mV then a further rest of > 5 days is recommended. If the variation is even greater, then in any case a reconditioning of the battery should be implemented.

- Results of reconditioning
  If during the capacity test the discharge voltages after 3.5 hours discharge are uniform, but fairly large variations then start to occur, then steps 1 to 7 of the reconditioning should be repeated. If an improvement occurs, then repeat steps 1 to 4 until capacity no longer rises. If however capacity falls with each cycle, then HOPPECKE should be informed so that further action may be initiated.

5.2 Spread of cell voltages

Too wide a spread of individual cell voltages may be determined during preventive maintenance from the two pilot cells or by measuring all cell voltages. Possible causes of a wide spread of cell voltages are:

- Variations in cell temperature.

- Differences in the electrolyte density of the cells.

- Varying electrolyte levels.

- Plate short-circuits in various cells.

- Varying states of charge

5.3 Insufficient capacity

Even when all cells have an adequate level of electrolyte, the density of the electrolyte may vary. This may lead to individual cells having different capacities. Insufficient capacity may be due to the following causes:

- Charging for too short a time.
- Electrolyte levels too low.
- Loose or oxidised terminals.

5.4 Insulation fault

If there is an insulation fault, leakage currents may reduce the available capacity, also leading to variations in cell voltage. Regular cleaning can prevent these leakage currents.

5.5 No battery voltage

If it is found that the system is no longer backed up by the battery, i.e. the complete battery voltage has failed, this may be due to the following causes:

- Fuses tripped
- Cable breakage
- Loose terminal

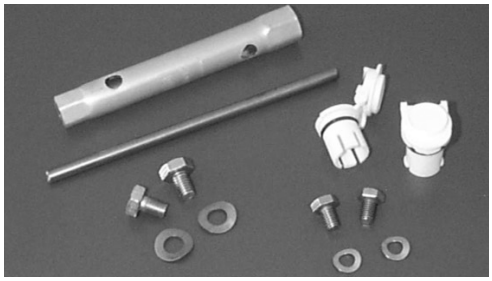
If a fuse has tripped, it should be ensured that none of the cables from the fuse box to the positive or negative terminals of the battery is damaged.

6. Test and measuring instruments, tools

All tools needed for maintenance and repair work may be ordered from the comprehensive range of HOPPECKE accessories. Under order number 7140200020 HOPPECKE offer a complete toolkit for the maintenance of nickel-cadmium batteries.

Measuring instruments and other equipment:

G01: Electrolyte density meter
G02: Voltmeter
G03: Insulation tester
G04: External charging and discharge unit
G05: Cell lifter
G06: Funnel
G07: Thermometer



Shown adjacent is the type HO27-02-1012 water replenishment cart for topping-up with distilled water in HOPPECKE NiCd FNC batteries.

This water replenishment cart is battery-powered and comes optionally with a 25 or 60 litre tank.

After the water replenishment cart has been in use it is connected to the power supply.
Leave the water replenishment cart connected to the mains until it is next required, so that the battery is fully charged.

7. Taking the battery out of service

- Discharge at rated current I5 down to a voltage of 1.0 V per cell.
- Replace the standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs by the yellow transport plugs. This is important to avoid atmospheric oxygen coming into contact with the electrodes.
- Clean the battery including all cells
- Store on pallets in a dry, frost-free room. The complete battery or the individual cells should be provided with a cover.

In principle, when taking the battery out of service, the standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs on the individual cells should be replaced by the yellow transport plugs. The standard vent plugs (hinged lid vent plugs) or AquaGen® vent plugs should be kept for subsequent use.

Depending on the length of storage after being taken out of service, the battery should be brought back into service again in accordance with these instructions.

7.1 Disposal

Disassembly and disposal of the battery should be carried out only by trained personnel. EC Directives 91156 (EEC) and 9386 (EEC) must be observed. Your local HOPPECKE representative will be pleased to give you a quotation for proper disassembly and disposal of your battery. The long-term objective of the Hoppecke recycling concept is that all NiCd cells brought into use are returned for proper recycling. HOPPECKE have a European-wide network of collection points for spent NiCd batteries. The benefit of the Hoppecke recycling concept is that the cadmium content of the batteries is recycled for use in the production of new NiCd batteries. The recycled cadmium is thus continually reused in a “closed loop”.

Further action, in particular the operation and maintenance of the battery, is described in the instructions “Operation and maintenance of stationary nickel-cadmium batteries with FNC cells”. It is essential that these instructions, which are supplied with the battery, are followed.

Used batteries with this symbol are recyclable goods and must be sent for recycling.
Used batteries which are not sent for recycling are to be disposed of as special waste under the appropriate regulations. HOPPECKE have a “closed loop” recycling system for NiCd batteries. Your local HOPPECKE representative will be pleased to give you a quotation for disposal of your battery.

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